DRAFT STUDY PLAN FOR SYNTHESIS AND INTEGRATION: DENALI LONG-TERM ECOLOGICAL MONITORING

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Integration and synthesis of Denali LTEM data began in the fall of 1998 with efforts focused in two areas. First, we needed to assimilate 1992-1997 data from four Denali LTEM projects (avian, vegetation, small mammal, and meteorology). Second, we needed to complete an initial integration study for presentation at the North American Symposium "Toward a unified framework for inventorying and monitoring forest ecosystem resources." We were successful on both fronts. All data now reside in a common format and have been imported into S-PLUS data frames, and we have a completed model of climate and small mammal abundance.

This report outlines a proposed study plan for the integration and synthesis of Denali LTEM data. Each enumerated item represents a proposed publication to be submitted to the indicated target journal. In addition, abstracts for items 1 and 3 have been submitted for presentation at the 1999 annual meetings of ESA and the Wildlife Society, respectively, and are included in this document as Appendix A. Other items may similarly be submitted for future presentations. Data management will always be an integral part of these studies and is not listed separately here. While we believe all topics listed here will have universal appeal, some have more of a theoretical bent (e.g., item 1), while others have direct management applications (e.g., item 4). Each item will help us better understand the Denali ecosystem and methods for monitoring it.

1. Modeling temporal patterns in small mammal abundance.

Target Journal: *Ecological Applications*

This is a continuation of the small mammal abundance model that was presented in Mexico this past fall where we used derived climate variables to predict small mammal abundance on a single 90 m by 90 m plot. The model will be refined and expanded to include other areas. This study is an example of how results from two projects can be combined to suggest underlying causal mechanisms that give rise to perceived patterns in the data.

Objectives:

- Fit a statistical model of small mammal abundance using derived weather variables as explanatory variables.
- Include *Microtus* species (*M. oeconomus* and *M. miurus*) in the model.
- Fit a similar model with data from plot RR2, the other plot used in all seven years.
- Test the model(s) more rigorously.

Methods:

We will combine *Clethrionomys* and *Microtus* species into a single log-linear model by including an indicator variable for genus, thus allowing for a more robust analysis given the small sample size. We will also be able to perform directs tests for differences between genera.

We will add plot RR2 to the analysis because it is the only plot in addition to RF1 that has been monitored in each year from 1992 to 1997. We will determine whether a similar abundance model can be fit for RR2 and examine the relationship between the two plots. We hypothesize that temporal patterns in abundance are the same for each plot with the only difference being a scaling factor. This will be tested by regressing RR2 abundance on RF1 abundance.

We will test the model(s) more extensively with simulations or other small mammal data from other locations. We will also extend the hindcast back as far as we have reasonable weather data (to the 1920s) and examine the resulting time series for periodicity and other temporal patterns.

2. Using robust estimation methods on small mammal populations in Denali.

Target Journal: *Journal of Wildlife Management*

Small mammal population analysis can be taken to the next level of sophistication with robust methods that include additional covariates (data from other projects) in the analysis (Pollock, 1982; Kendall and Pollock, 1992). This is truly an integrated approach, using all available information to analyze small mammal populations. Direct tests become possible, testing for significant relationships between capture probabilities and other biotic and abiotic factors, testing for differences between years (temporal), and testing for differences between locations (spatial).

There is a subtle yet important distinction to be made between this study and item 1. In that study, small mammal data are collected and analyzed independently of the climate data. Once abundance estimates are computed, we look for a relationship between them and the derived climate variables. In this study, we propose to use the climate data and other relevant data directly in obtaining the abundance estimates themselves. Generating abundance estimates from mark-recapture data requires estimating capture probabilities. Non-robust methods estimate these probabilities from just the observed recapture data, whereas robust methods allow us to model them as a function of several coviariates such as climate and habitat type.

Another more practical distinction must be made. Study item 1 results in a predictive model that we can use to predict small mammal abundance given the necessary climate data. Robust estimation uses covariates to generate better abundance estimates, but it does not give us a model for predicting abundance. The products of these studies are very different.

Objectives:

- Use robust estimation methods with 1992 to 1998 small mammal capture/recapture data, utilizing data from other LTEM projects as covariates.
- Test for temporal and spatial differences in abundance.

Methods:

Methods used to date to analyze small mammal data have limited the analyses to looking at individual plots at a single point in time. We will extend this analysis with the use of robust estimation methods that will allow us to include multiple locations and times in a single model. Additionally, we will use other data (weather, vegetation, avian, etc.) to perform an integrated analysis whereby we can test for significant relationships between varied data sets.

Robust methods permit us to directly test for temporal and spatial differences. We will test for differences between monitoring locations (watersheds) and between time periods (within and between years).

3. A comparison of avian monitoring methods in Denali LTEM.

Target Journal: *Conservation Biology*

Currently both MAPS and point counts are being used to monitor avian populations in Denali. One is a fairly simple, inexpensive method that basically addresses presence/absence (point counts), while the other involves greater cost and effort to estimate productivity and survival (MAPS). Where do they overlap, giving us the same information? Do their results agree, i.e., are they detecting the same species? Can we approach this as a calibration problem where we try to calibrate a less expensive technique to a more expensive one, hence gaining “adequate” information at a reduced cost? Or is the less expensive method redundant and unnecessary given the data obtained by the more expensive method?

Objectives:

- Compare results from MAPS and point counts.
- Test for effectiveness in detecting trends.
- Address calibration possibilities such as less-frequent MAPS monitoring to support annual point counts.

Methods:

MAPS and point counts give us some basic information in common such as presence/absence data by species. We will investigate the concordance between these methods and try to understand reasons for any differences we find. We will employ multivariate techniques to determine similarity or difference between detected community structure.

Using simulations, we will introduce trends in avian populations and determine performance of each method in detecting them.

We will explore the possibility of using the results from the first objective to “calibrate” the point count data to the MAPS results. This may allow us to reduce or eliminate MAPS efforts and gain more from the less expensive point counts. Should we find that this is not possible, we will consider whether point count data is adequately represented within MAPS, suggesting the redundancy of conducting point counts.

4. Measuring the health of a national park.

Target Journal: *Environmental Monitoring and Assessment*

This refers to the “gas gauge” idea discussed in recent conversations. Can we provide the park service with an overall measure of the health of Denali? Can we track its health through time and make general observations such as whether its health is improving or deteriorating? This would undoubtedly require some prioritizing of just what should go into such a measure, which would be a worthwhile exercise in and of itself.

Objectives:
- To develop a “gas gauge” measure of the health of Denali National Park and Preserve that can be determined annually.

Methods:

The health of an ecosystem involves inputs from many sources. We will begin by determining a subset of those sources to include in the measure. One possibility is to begin with each project within Denali LTEM and synthesize an annual summary metric for each that incorporates a relevant indication of "standing crop" and "productivity", and is on a continuum from some “ideal” to a “worst case” scenario. These summary metrics will need to be considered carefully because simple averages may not be adequate. Considering small mammal populations for example, the decimation of one local population could be countered with the strong growth of another. An average metric would indicate stability when in fact there could be striking changes taking place.

Once a suite of metrics is determined, we will need to determine whether we can combine them into a single “gas gauge” measure of the health of Denali. Alternatively, we may have to keep them separate as in an “instrument panel” that together represents the state and direction of the ecosystem. The same concern arises regarding average measures. If small mammal populations crash, but avian populations increase, then an average measure could suggest a false stability. We will run several simulation scenarios to develop the final measure and have some sense of what the measure means.

Karr (1981) presented an index of biotic integrity (IBI) for quantifying the status of fish communities in degraded streams. Once we have identified the necessary components of our measure, one possibility will be to consider adapting the IBI to reflect the amount of degradation to the Denali National Park and Preserve ecosystem.

5. Monitoring strategies for Denali LTEM: facing reality.
Target Journal: Environmental Management

This essentially picks up where our scaling-up report left off. We will refine the process, select monitoring sites, and devise a working schedule of what is done, where it is done, and how often it is done. The timing of this study is best left until some key questions are resolved for the entirety of Denali LTEM. Specifically, will we monitor the entire park or only the road corridor? and can monitoring efforts be within sight of the park road?

Objectives:
- Develop a working strategy for monitoring Denali National Park and Preserve.
- Test the effectiveness of this strategy for detecting potential trends.

Methods:

We will continue exploring options for the scaling up of Denali LTEM. Using the rotating intensity schedule outlined in our report, we will give specifics of the monitoring strategy, select a sample of monitoring sites, and propose a schedule for carrying out stated objectives. This unified framework focuses on the current status and the underlying processes at work in the ecosystem to hopefully anticipate future trends.

We will use simulations to impose a trend on some attribute of interest and run our proposed monitoring scheme to determine the probability of detecting the trend. Is it adequate to only visit a site occasionally and perhaps only monitor it intensively once in twelve years? Simulations would help provide us with some suggestions of minimum effort required.

Proposed Time Line

Analysis for each study item described here will be performed separately and to completion (shaded cells indicate time for analysis). There will, however, be some overlap in report and manuscript writing. Deliverables from each study include a report to USGS-BRD and a manuscript for publication in a peer-reviewed journal. Additional deliverables may include posters and/or presentations.

	1. Small Mammal Model	2. Robust Estimation	3. MAPS vs Point Counts	4. Index of Ecosystem Health	5. Scaling-up Protocols
Feb 1999					
Mar					
Apr	Analysis complete				
May	Report complete				
Jun					
Jul		Analysis complete			
Aug	ESA Poster	Report Complete			
Sep		TWS Paper			
Oct	MS 1st draft		Analysis complete		
Nov			Report complete		
Dec		MS 1st draft			
Jan 2000					
Feb				Analysis complete	
Mar				Report complete	
Apr			MS 1st draft		
May					Analysis complete
Jun					Report complete
Jul				MS 1st draft	
Aug					MS 1st draft

References

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21-27.

Kendall, W.L., and K.H. Pollock. 1992. The robust design in capture-recapture studies:a review and evaluation by Monte Carlo simulation. Pages 31-43 in D.R. McCullough and R.H. Barrett (eds.) Wildlife 2001 Elsevier, London.

Pollock, K.H. 1982. A capture-recapture design robust to unequal probability of capture. J. Wildl. Manage. 46:752-757.

Appendix A: Submitted Abstracts

Submitted to: Ecological Society of America 8-12 August 1999

Modeling temporal patterns in microtine abundance in Denali National Park and Preserve.

Small mammal populations have been monitored in Denali National Park and Preserve since 1992. In the ensuing seven years, interannual fluctuations in abundance have been observed for two genera of microtines (*Clethrionomys* and *Microtus*), with differences between years as much as an order of magnitude (ranges were 9 to 95 ha^{-1} and 6 to 73 ha^{-1}, respectively). Using meteorological data from the same time period, we defined three annual indices that describe aspects of climate thought to affect small mammal populations: winter severity, spring onset, and spring rainfall. With the 1992-1997 end-of-summer abundance estimates for each genus as the response variable, we fit a log-linear regression model with the three climate indices and an indicator variable for genus (overall $P<0.0001$). Significant differences between genera were found for all indices except winter severity. When the model was used to predict the 1998 abundance for each genus, the 95% prediction intervals did not contain the observed abundance estimates; however, the confidence intervals for observed abundance did overlap with the prediction intervals. We also used the models to estimate abundance from 1955 to 1991 and found concordance with known fluctuations for both genera. This model supports the hypothesis that microtine abundance is driven by environmental conditions with little carry-over effect from the previous year.

Submitted to: The Wildlife Society 7-11 September 1999

Estimation of vital rates of small mammal populations in Denali National Park and Preserve in the presence of immigration and emigration.

Small mammal populations have been monitored in Denali National Park and Preserve on consistent plots since 1992. Interannual dynamics of abundance have been manifest with abundance of northern red-backed voles *(Clethrionomys rutilus)* fluctuating from 9 ha^{-1} to 95 ha^{-1} in this seven year period. We have further scrutinized these data to examine patterns of demographic processes among years of high and low abundance. Using the robust design methods described by Kendall et al. (1997), we estimated survival, recruitment, and emigration parameters for two plots in years of high abundance (1993 and 1995) and contrasted these values with estimates in years of low abundance (1994, 1997, and 1998). Models were constructed in which vital rates were allowed to be year-specific, vital rates were categorized into good and poor years (based on abundance), and vital rates were constant with respect to time. Model selection criteria (Burnham and Anderson 1998) were employed to delineate differences in these vital rates. For within season modeling, we found plot effects on survival and recruitment (small scale geographic differences) to be of greater magnitude than within-season temporal effects.